Observations and Modeling of Saharan Dust Interaction With A Tropical Cyclone

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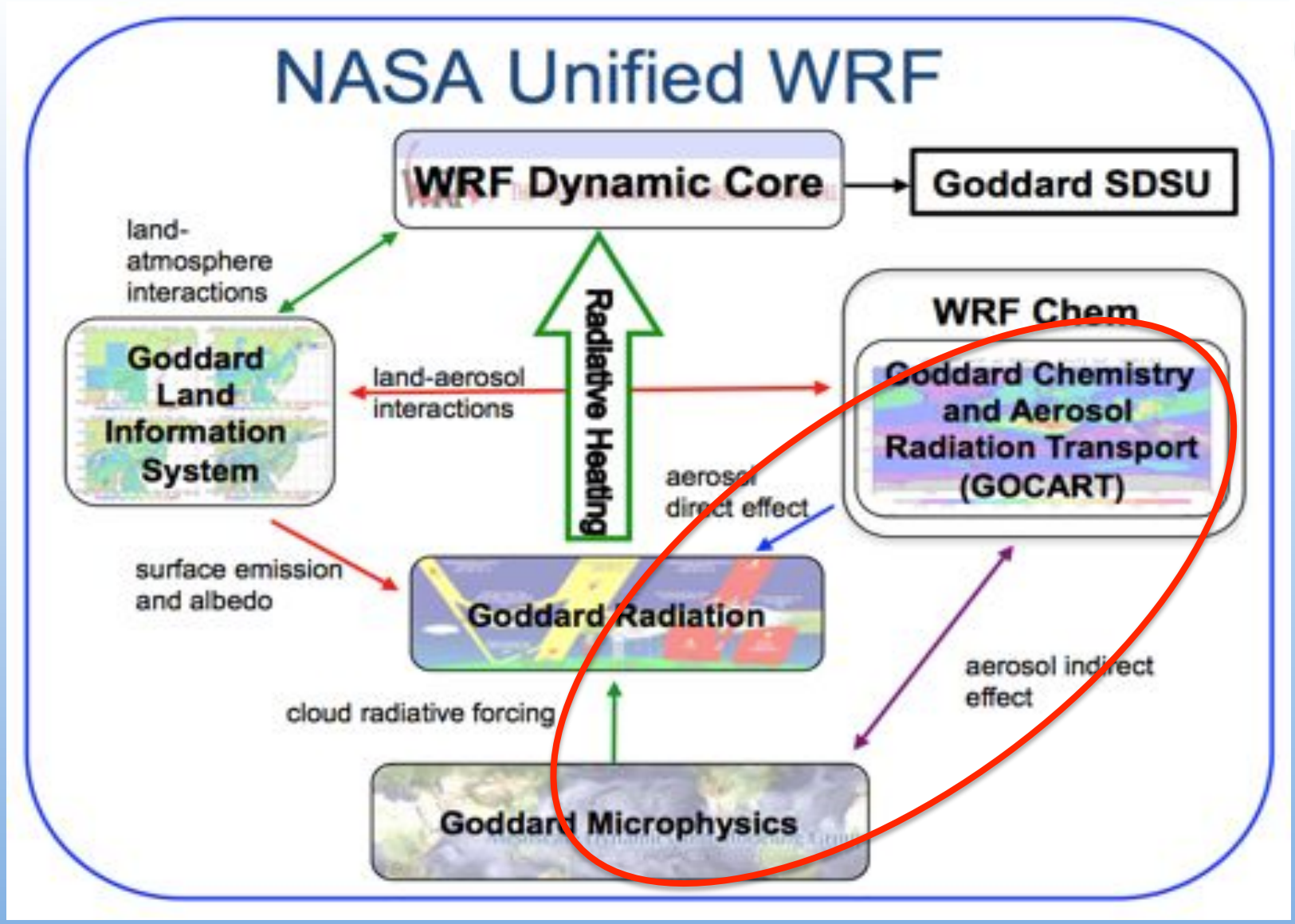
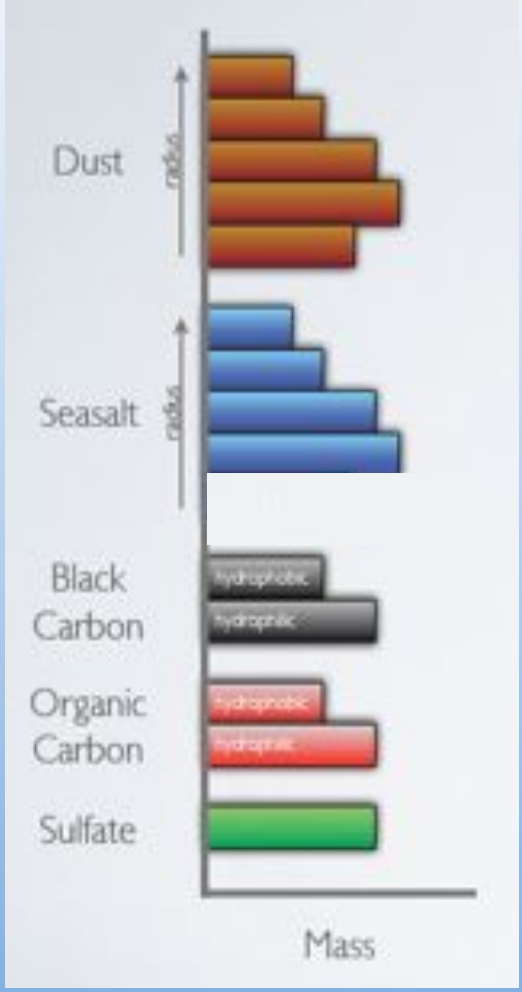
Background

- Conflicting views on role of the SAL pre- and post-genesis (Karyampudi and Carlson 1988, Dunion and Velden 2004, Braun 2010, among others)
- Early dust-impact studies claimed negative impacts, but had unrealistic dust distributions (Zhang et al. 2007, 2009)
- More recent work with more realistic dust suggest possible positive impacts in some cases (Herbener et al. 2014)



Shi, J. J., T. Matsui, W.-K. Tao, C. Peters-Lidard, M. Chin, Q. Tan, K. Pickering, N. Guy, S. Lang, and E. Kemp, 2014: Implementation of an Aerosol-Cloud Microphysics-Radiation Coupling into the NASA Unified WRF: Simulation Results for the 6-7 August 2006 AMMA Special Observing Period. *Quart. J. Roy. Meteor. Soc.*, **140**, 2158-2175, doi:10.1002/qj.2286.

Aerosol-Microphysics Schemes



Aerosol-Microphysics Coupling
(done in Goddard 5-class 3-ice MP scheme only)

- CCN based on Koehler curve (Koehler *et al.*, 2006; Andreae and Rosenfeld, 2008)
- IN based on Demott *et al.*(2010)
- Both CCN and IN are diagnostic parameters only

Aerosol-Radiation Coupling
(done in Goddard LW/SW radiation schemes only)

- Aerosols predicted from WRF-Chem/GOCART are used to calculate radiative parameters to account for the aerosol scattering and absorption effects in the atmosphere.

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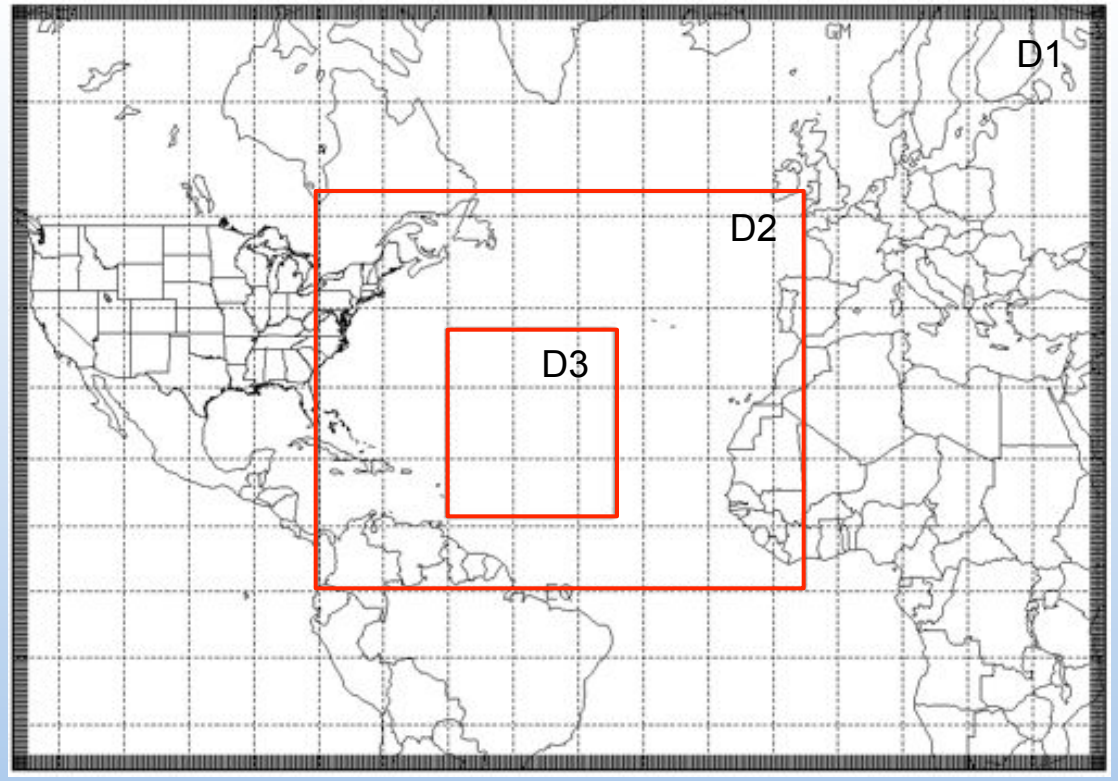


Physics:

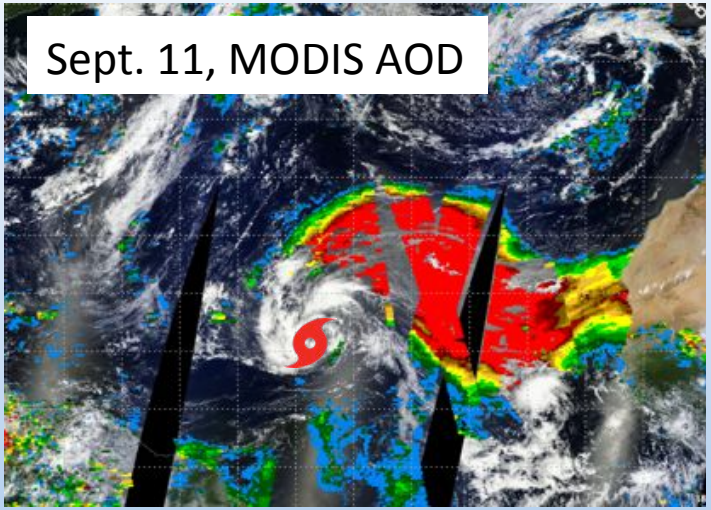
- Grell-Freitas ensemble Cu parameterization
- Goddard microphysics 3-ice with aerosol
- 2014 Goddard radiation scheme for both longwave and shortwave
- YSU scheme PBL scheme
- Monin-Obukhov (MM5) sfc layer
- Unified Noah land-surface model

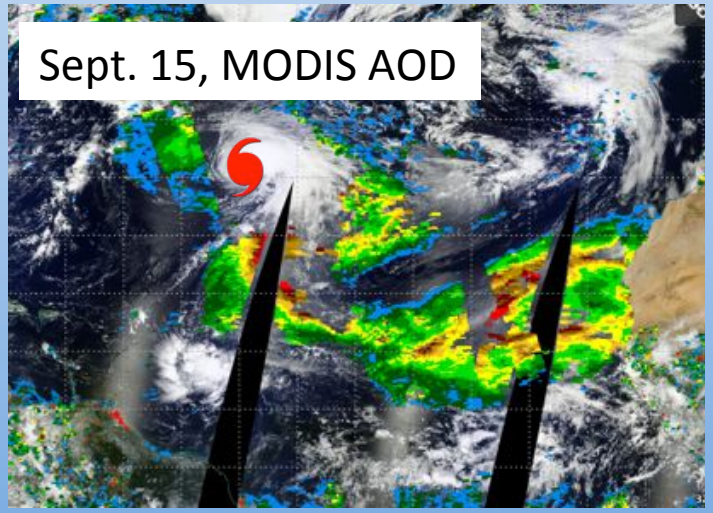
Resolutions: 27, 9 and 3 km
Grid size: 601X421, 802X655, 832X931, and 61 vertical layers
Δt = 60 seconds
Starting time: 00Z 09/10/2012
End time: 00Z 09/17/2012
Initial and Boundary Conditions: NCEP/GFS
SST: ERA-Interim, updated every 24 hours

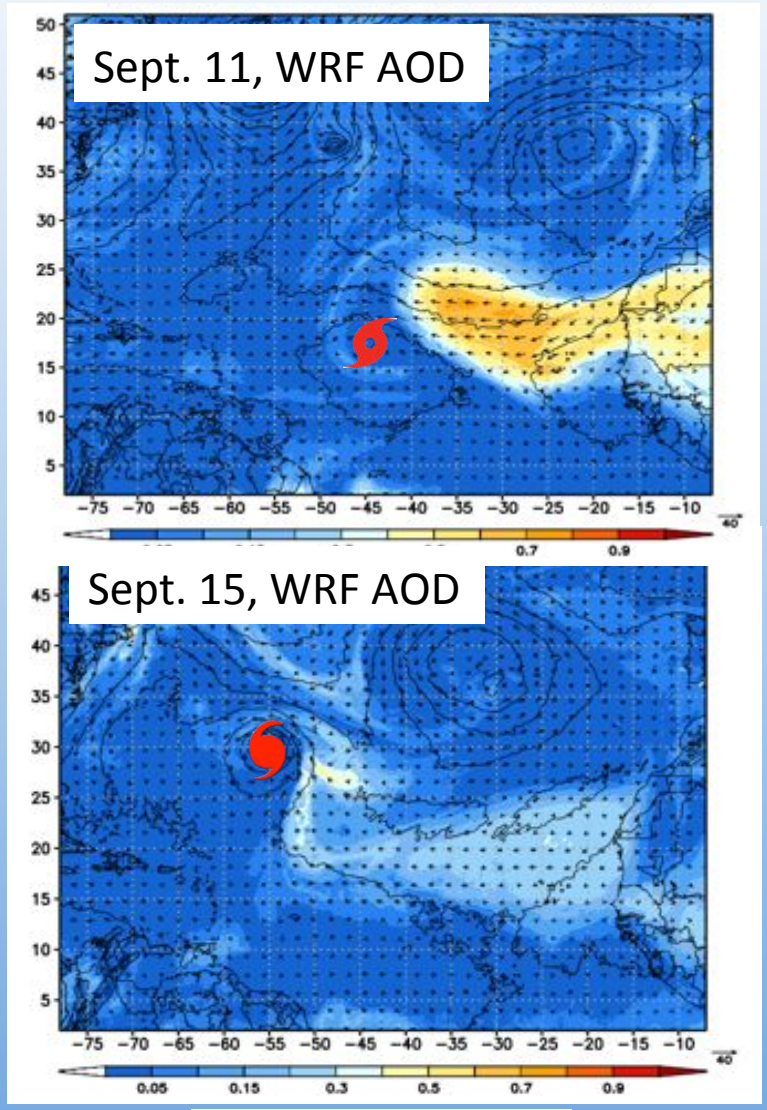
Experiments:

- CNTL: No dust
- AMR1: Dust acting as IN&CCN
- AMR2: Dust acting as IN only
- AM1: Microphysical coupling only
- AR1: Radiative coupling only

MODIS vs. WRF AOD

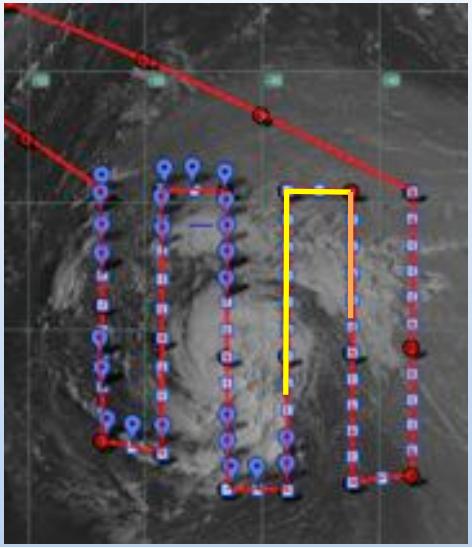


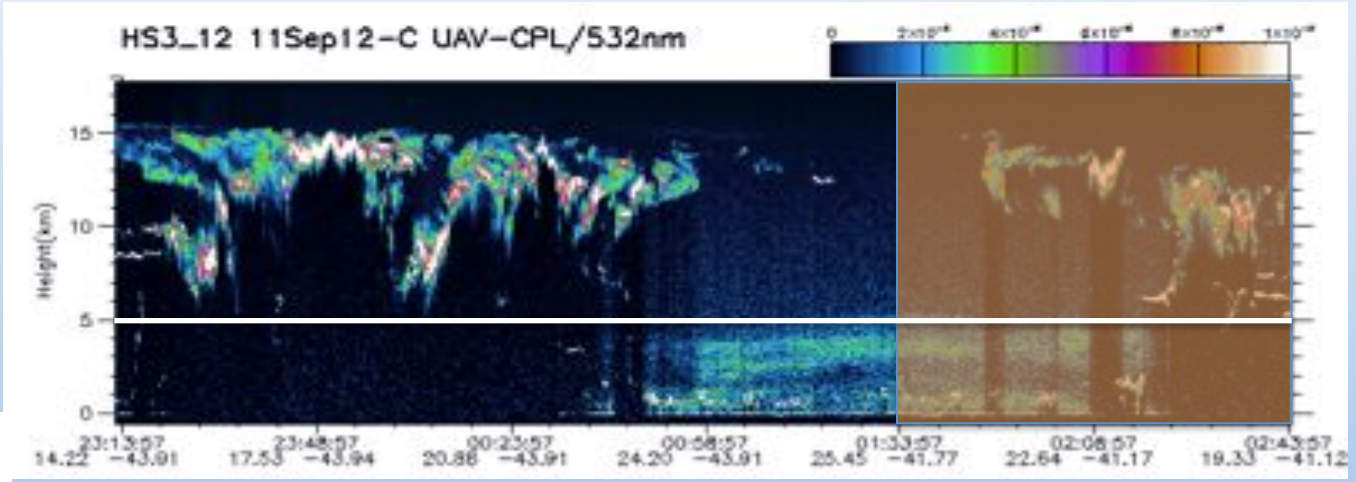


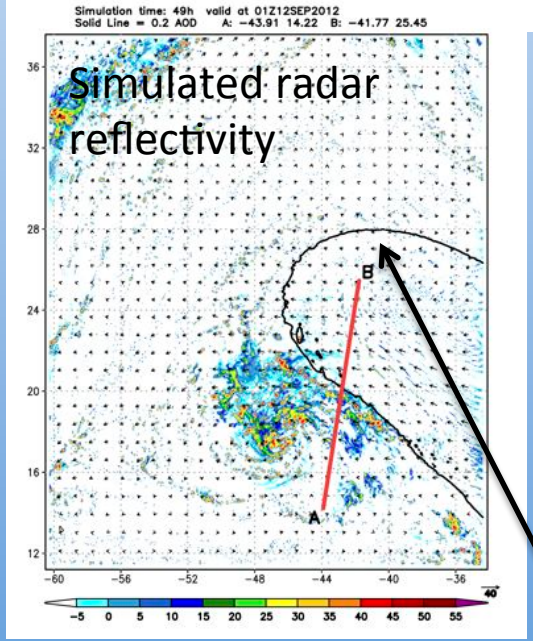


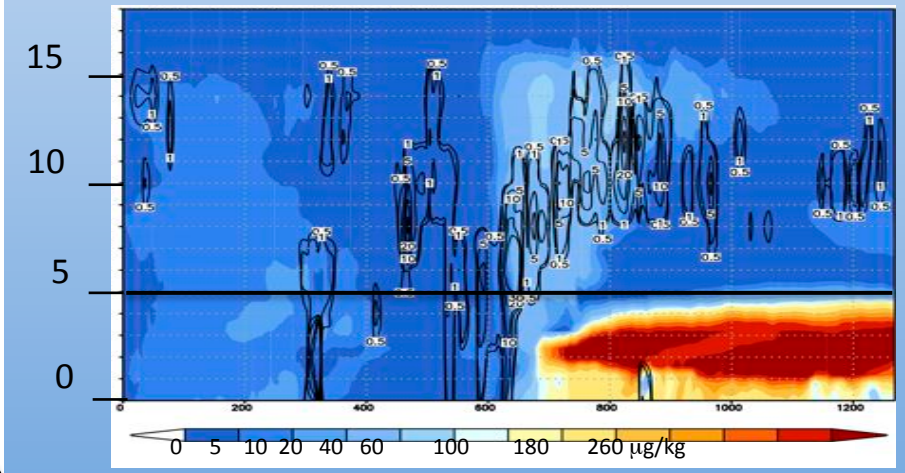
Dust Vertical Structure Compares Well To CPL

Comparison with CPL at 0100 UTC 12 Sept









South

North

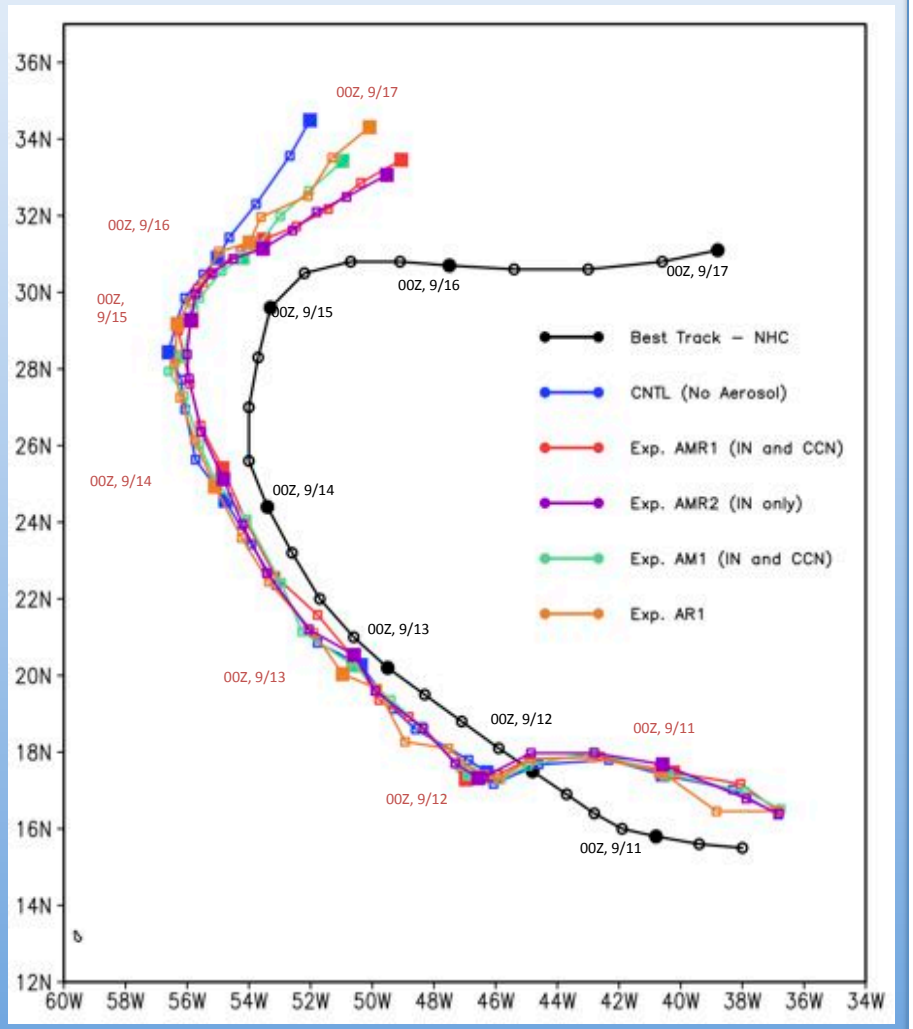
SAL Dust Boundary

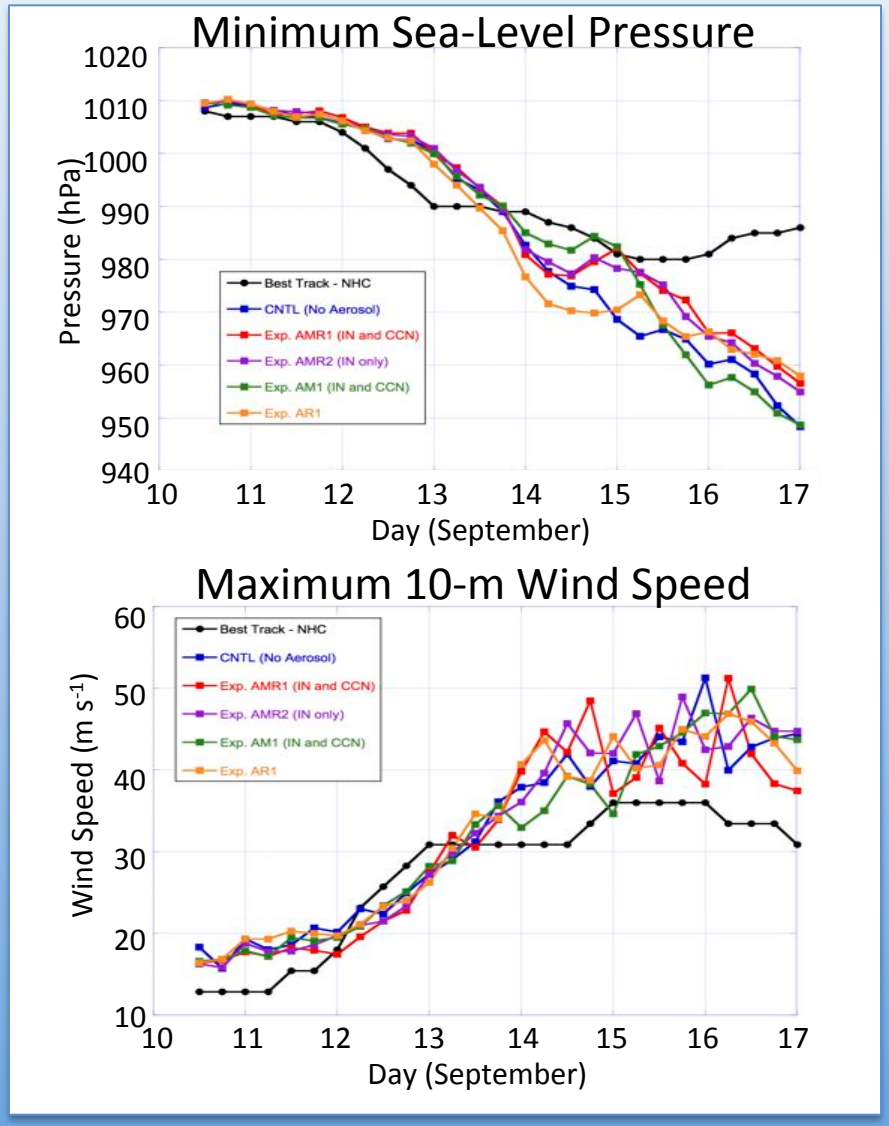
Dust mass (shading)

Total hydro-meteor mass (black contours)

The Quick Answer On Dust Effects

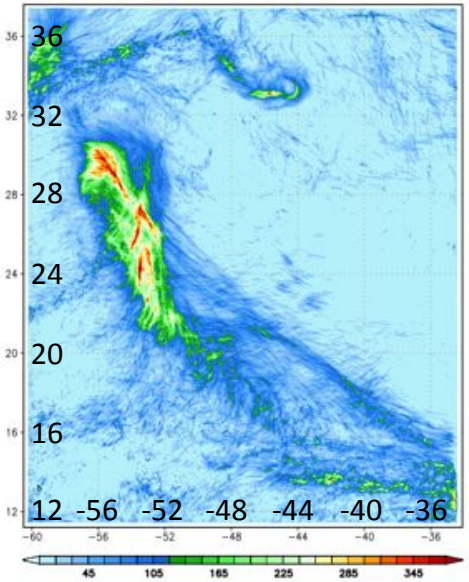
Saharan dust has little apparent impact on storm intensity



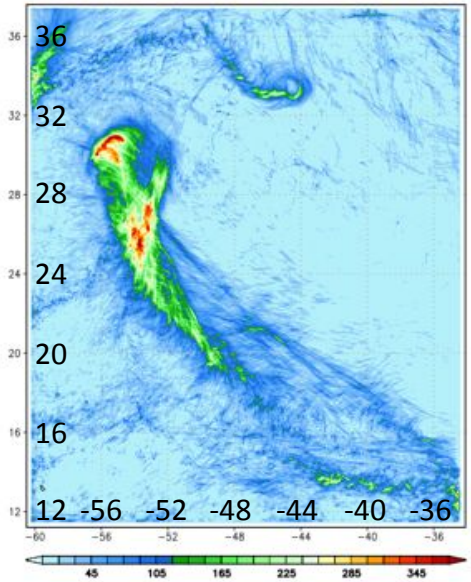


Impacts on Accumulated Precipitation

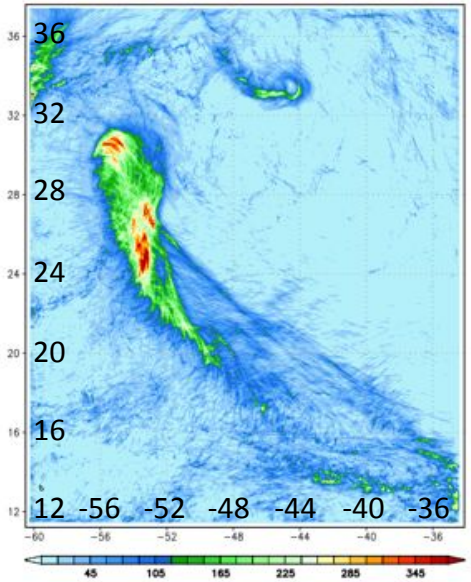
CNTL



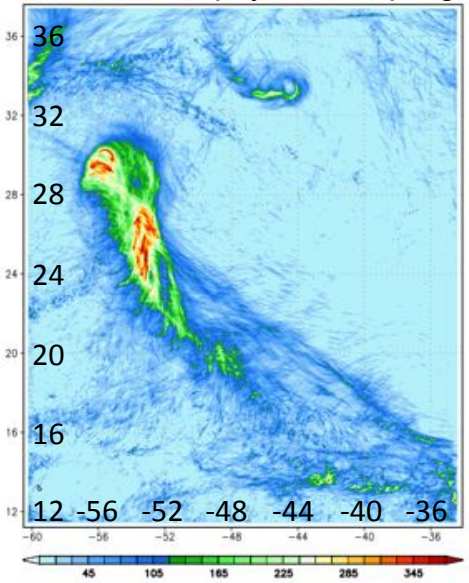
AMAR1 (CCN&IN)



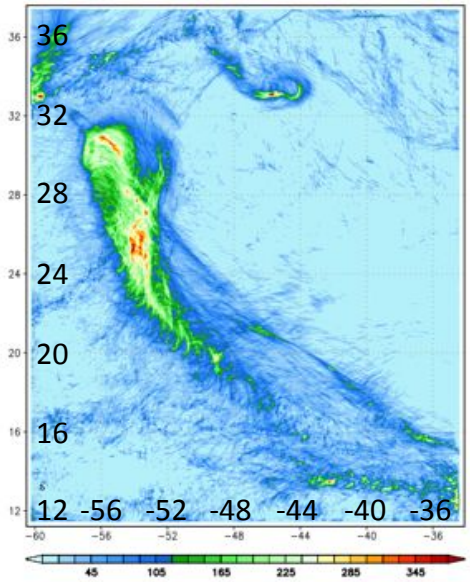
AMAR2 (IN only)

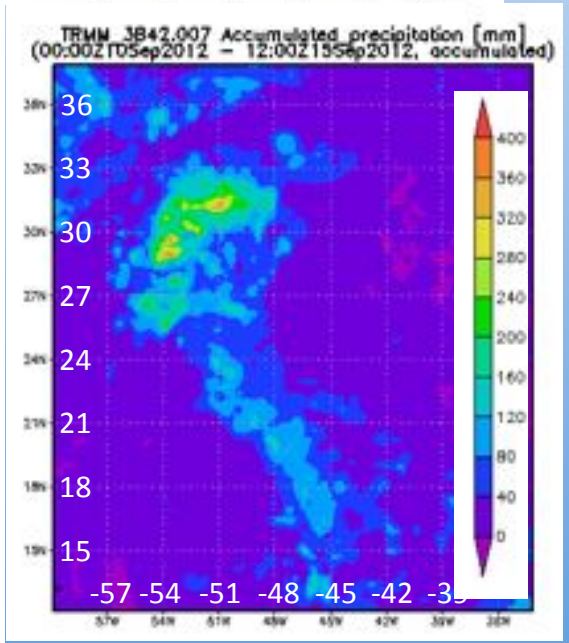


AM1—Microphysics Coupling



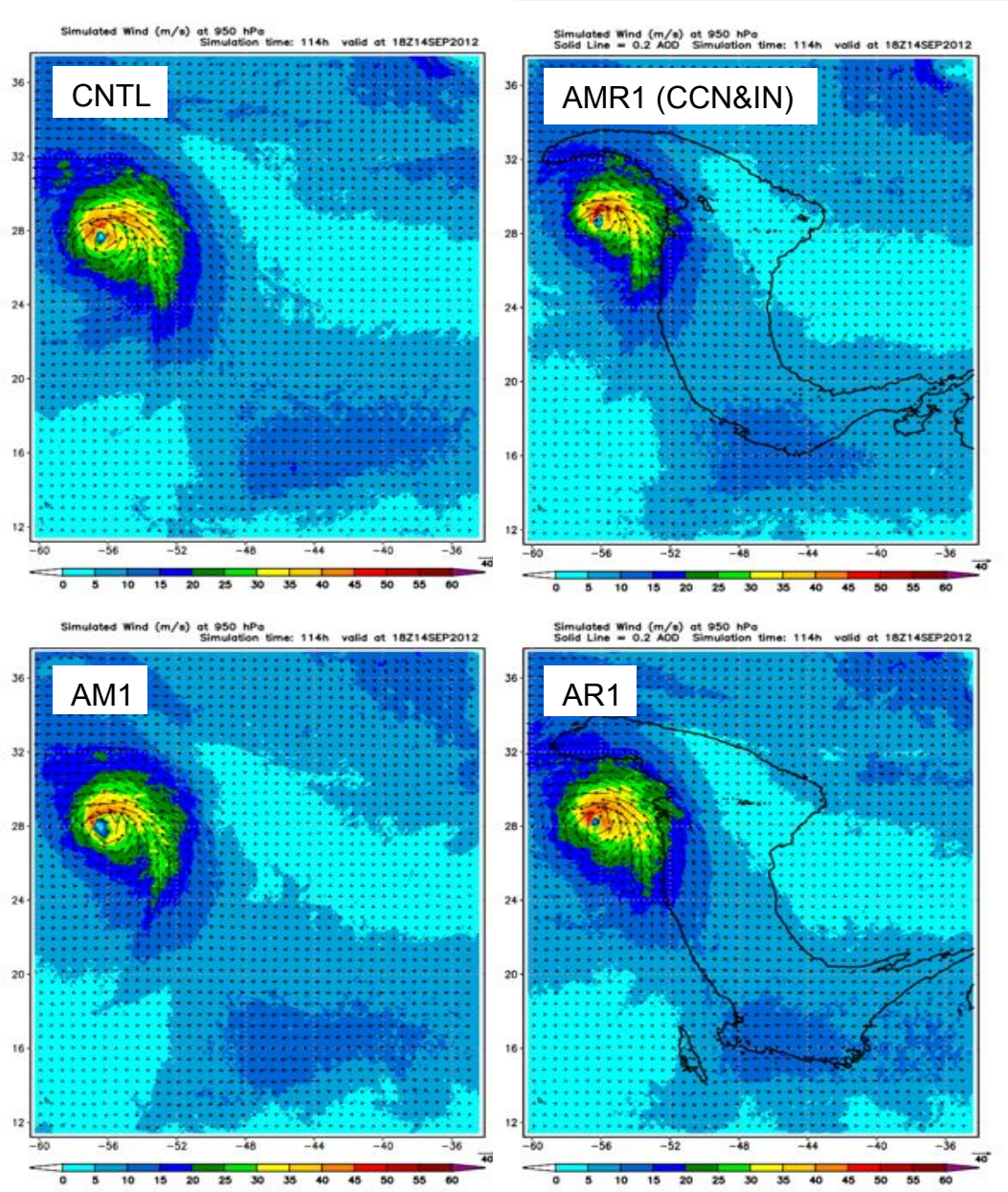
AR1—Radiation Coupling





Accumulation from 00 UTC 10 Sept. to 12 UTC 15 Sept.

Impacts on Wind Structure

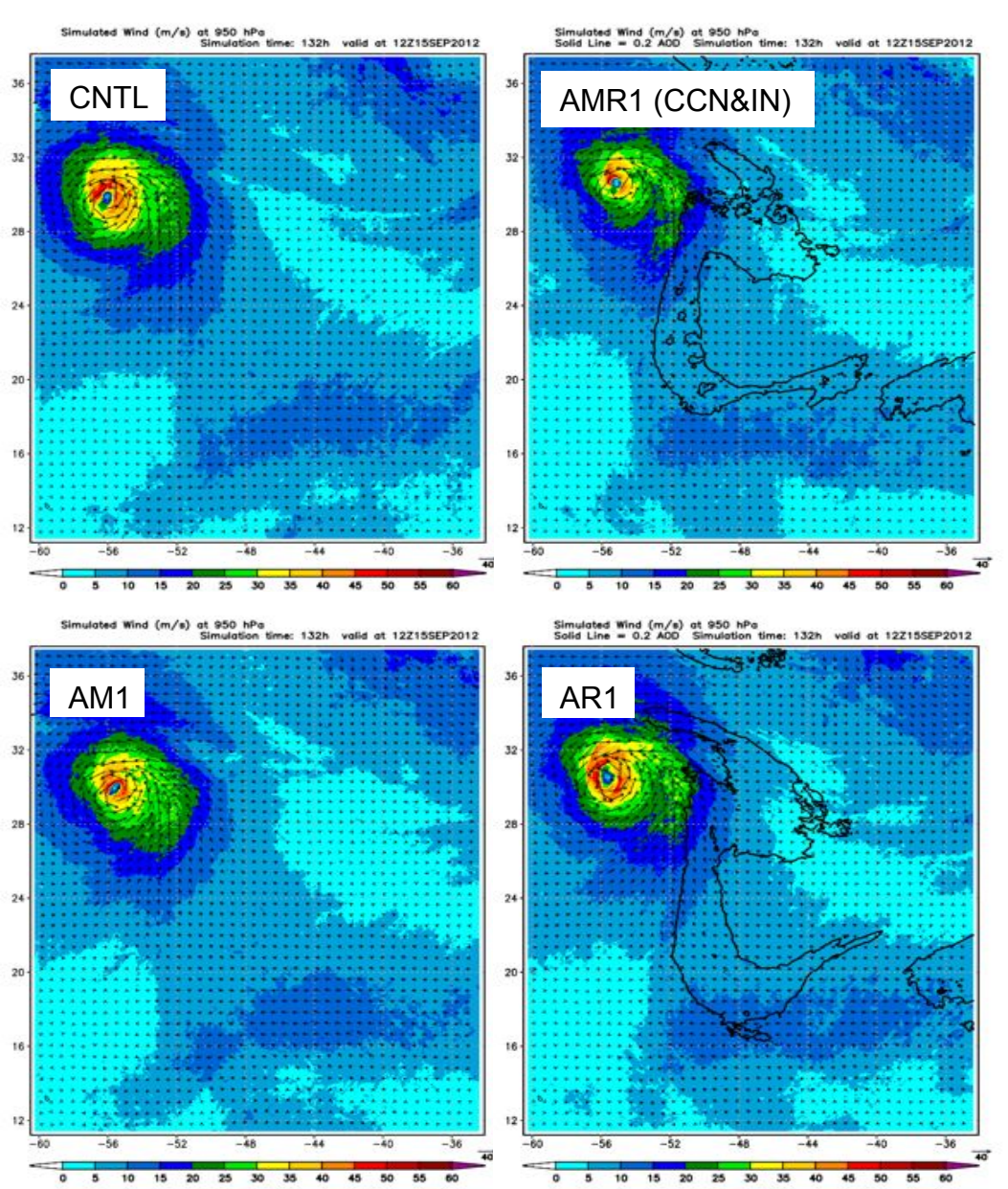


950 hPa wind speeds at 114 h (18 UTC 14 September)

Black outline shows dust boundary (0.2 AOD). Not shown in AM1 case because AOD not calculated when radiation is turned off.

Smaller storm seen in AMR1 case.

Impacts on Wind Structure



950 hPa wind speeds at 132 h (12 UTC 15 September)

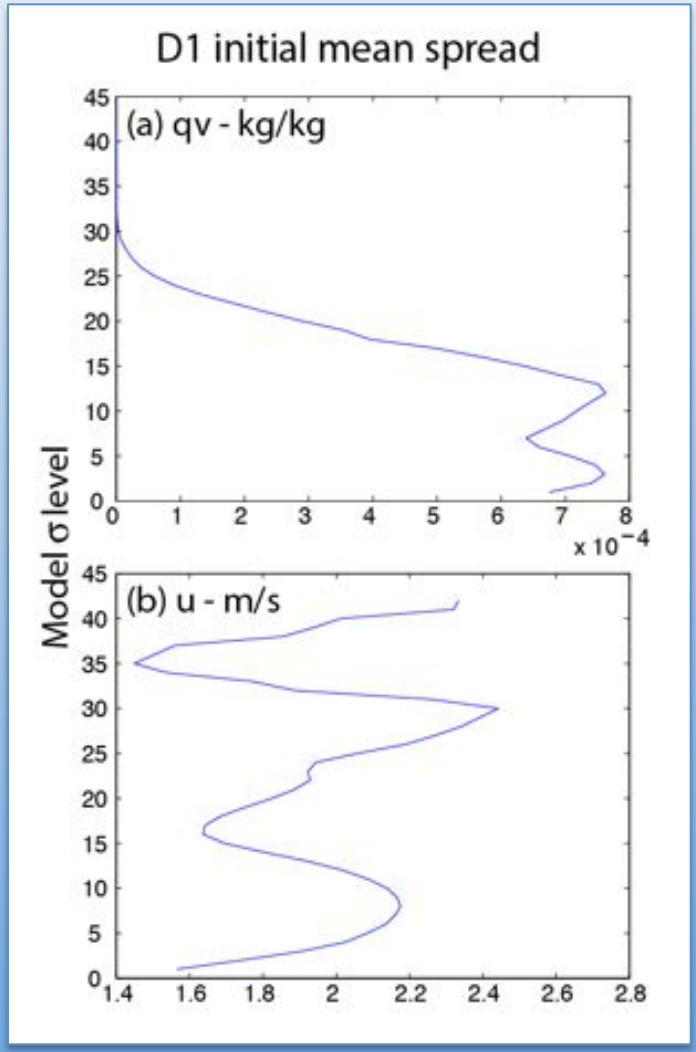
Black outline shows dust boundary (0.2 AOD). Not shown in AM1 case because AOD not calculated when radiation is turned off.

Smaller storm seen in AMR1 case. AM1 and AR1 both produce larger storms than AMR1.

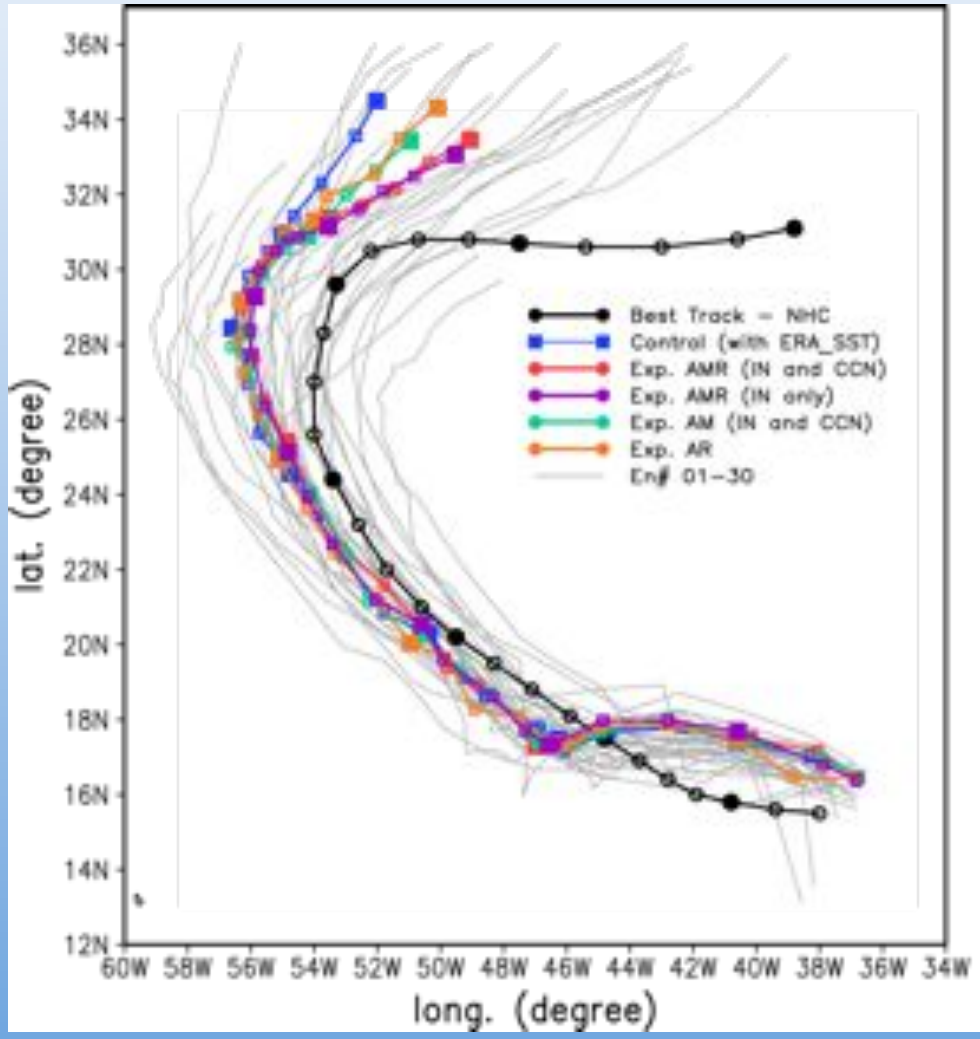
Are differences in size (intensity) just due to random perturbations?

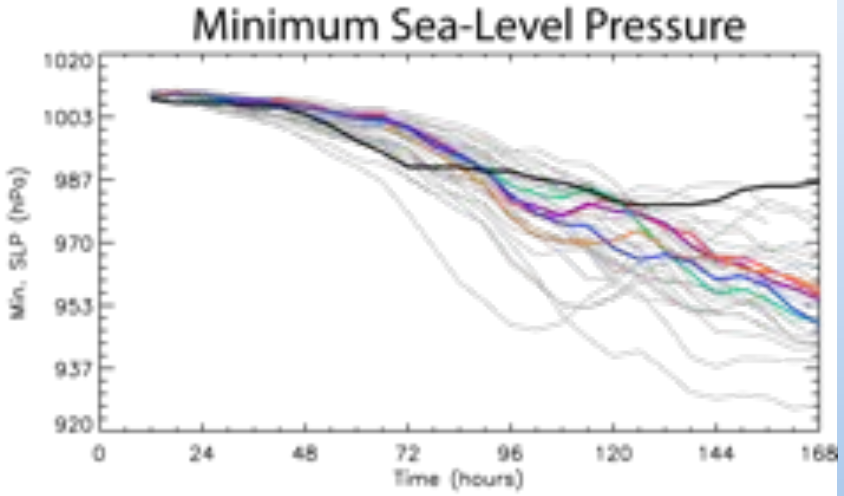
Description of Ensembles

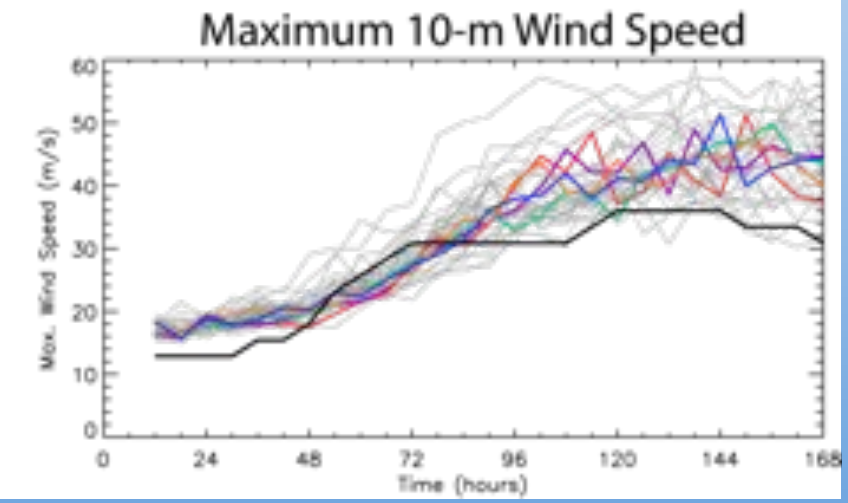
- WRF-VAR background error used to create large-scale, random perturbations to wind, temperature, pressure, and moisture.
- Perturbations added to NCEP GFS analysis/forecast to create initial/ boundary conditions for 30-member ensemble
- Initial condition spread commensurate with analysis error.



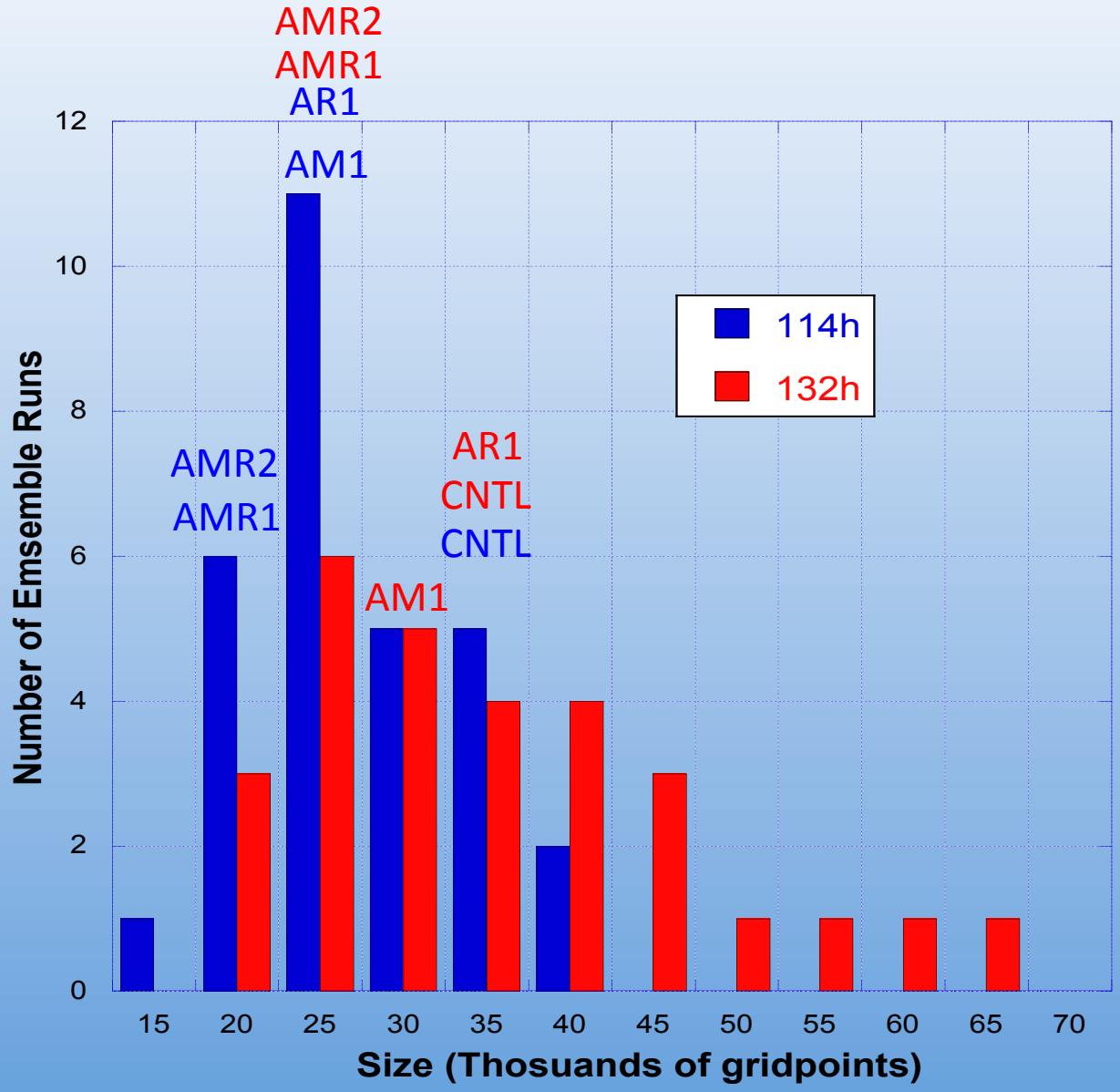
Low Spread In Sensitivity Runs Compared To Ensembles







Ensemble Storm Sizes



Size=area with winds > 34 kt

Bar chart shows only ensemble members

Text shows sensitivity runs

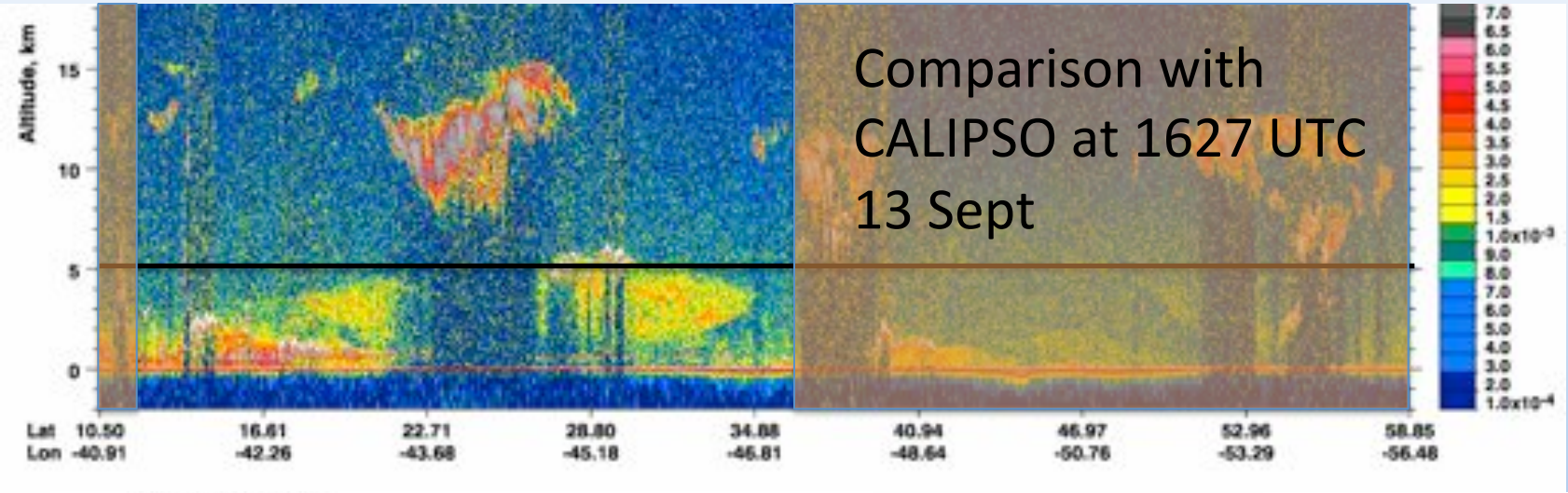
Conclusions

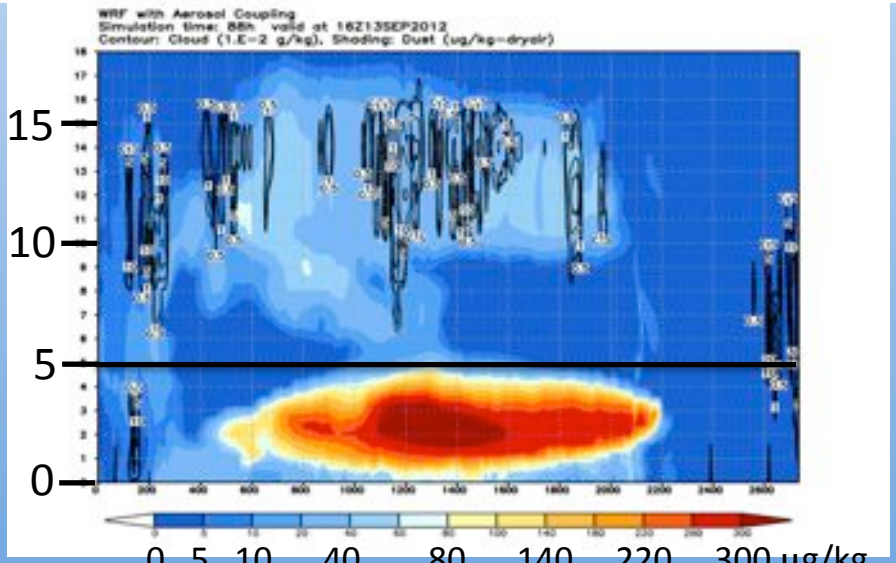
- Little impact on storm intensity and track through 5 days
- Simulation differences from physics sensitivity runs smaller than spread caused by random perturbations
- Possible tendency for reduced size, but requires aerosol ensemble runs to verify

Future Work

- Perform ensembles of AMR1 case, compare to Control ensemble
- Examine differences in storm structure
  - Radius of max wind, hurricane-force winds, TS-force winds
  - Impacts on thermodynamic fields
- Find time to write it up!

Dust Vertical Structure Compares Well To CALIPSO





Dust mass (shading)

Total hydro-meteor mass (black contours)